MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

Trimester 3, 2016/2017

EEN7116 – ELECTRONIC PACKAGING
(ALL GROUPS)

3 JUNE 2017
9:00 a.m. – 12:00 p.m.
(3 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 10 pages with 4 questions only.
2. Answer **ALL** questions. All questions carry equal marks of 25. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.
4. An Appendix is provided.

Question 1

(a) Describe the steps involved in laminated ceramic technology using suitable diagrams.

[12 marks]

(b) Explain the distinction between high temperature co-fired ceramic (HTCC) and low-temperature co-fired ceramic (LTCC) processes in terms of curing temperature and metalization.

[3 marks]

(c) Briefly explain what chip-scale packaging (CSP) is, and list THREE (3) advantages of CSP.

[3 + 3 marks]

(d) Through Silicon Via (TSV) is the current state-of-art that enables multiple semiconductor dies to be stacked on top each other within a package. Combine with CSP approach, TSV and die-stacking allows un-paralleled integration, such as system-in-package (SiP) where memory, micro-processor and special functions circuits (e.g. CMOS imager or communication circuits) can be integrated within a single package. List and briefly describe the key semiconductor fabrication technology that enable mass production of TSV.

[4 marks]

Question 2

A simplified view of the cross section of a micro-processor integrated circuit (IC) is shown in Figure Q2. The IC requires a power supply of 1.5V to function properly. Average current consumption (I_{CC}) of the IC can range from as little as 20 mA to as high as 400 mA, depending on the clock frequency supplied to the IC. At I_{CC} = 400 mA, the micro-processor is running at 1.5 GHz clock frequency.

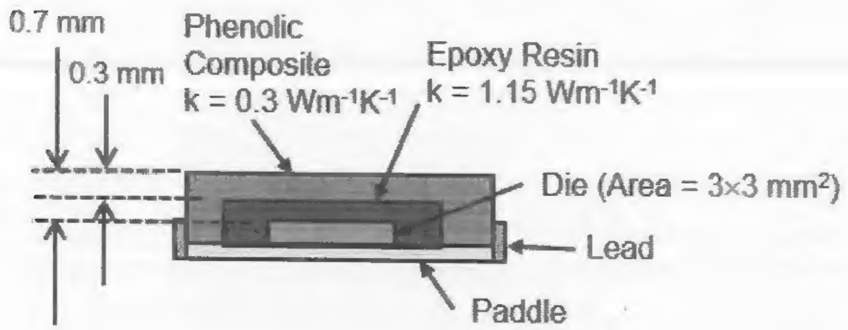

Figure Q2.

Continued...

(a) Determine the power dissipation of the IC at 1.5 GHz clock frequency.

[3 marks]

(b) Assuming the outer surface of the package is maintained at 25°C via some cooling mechanism, and the heat transfer is mainly through the upper surface of the die, perform an analysis to determine if the die would overheat at 1.5 GHz clock frequency if maximum allowable operating temperature of the die is 125 °C.

[11 marks]

(c) Calculate the temperature at the interface between the epoxy resin and phenolic composite layers when the die is running at 1.5 GHz clock frequency.

[4 marks]

(d) Based on the results of (c), estimate the shear strain at the interface between the epoxy resin and phenolic composite. Assume the initial dimensions of the epoxy resin and phenolic composite layers are 3mm × 3mm at room temperature of 25°C and the material expands at the same rate in all directions. The mechanical properties for epoxy resin and phenolic composite are as follows:

	CTE ppm/°C	Young's Modulus N/mm^2 or MPa
Epoxy Resin	55	10500
Phenolic Composite	70	8500

[7 marks]

Question 3

(a) List out THREE (3) physical properties of packaging for integrated circuit (IC) that runs at frequency in excess of 1 GHz.

[3 marks]

(b) Figure Q3A shows the cut-away views of two QFN (quad-flat no lead) packages. The QFN packages will be soldered onto a PCB (printed circuit board) with ground plane. Which package is better in terms of signal integrity and bandwidth? Briefly explain your argument.

[5 marks]

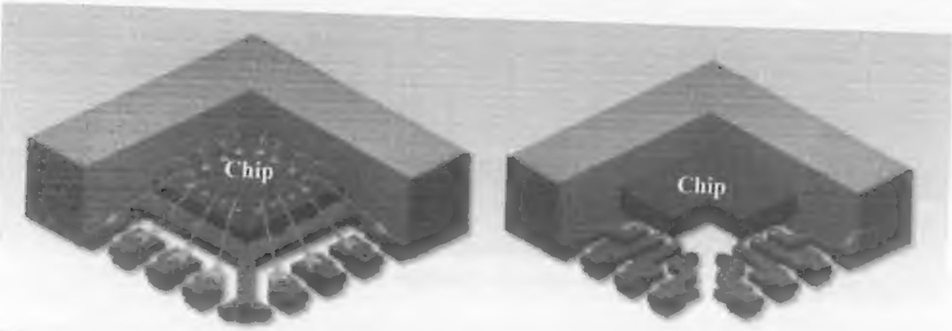

Figure Q3A – Cut-away views of QFN packages (a) with bond-wire interconnection (b) using flip-chip approach.

(c) A portion of the top view of a PCB with two chips (in TQFP and QFN packages) is shown in Figure Q3B. Chip 1 on the left contains a high-speed transmitter (TX) on the die while Chip 2 on the right contains a receiver (RX) on the die. The TX and RX are connected by an 11.0 mm long copper trace on the PCB. The width of the trace is 0.203 mm (8 mils). A ground plane is underneath the trace. The PCB substrate that separates the trace and ground plane, has a thickness of 0.46 mm with $\varepsilon_r = 4.4$ and $\mu_r = 1.0$. Ignoring interaction with adjacent traces, the equivalent electrical circuit between TX and RX is shown in Figure Q3C, and the frequency response from 10 MHz to 10 GHz is shown in Figure Q3D.

(i) Assume V_s (of Figure Q3C) is a pulse generator, sending a stream of periodic digital pulses with amplitude of 1.2V, pulse width of 2 nanoseconds, and rise/fall time of 200 picoseconds. Estimate the bandwidth of the digital pulses, stating the rule-of-thumb used.

(ii) Briefly explain the need for the transmission line element in the equivalent circuit of Figure Q3C.

(iii) The time-domain waveforms of the received voltage at RX (i.e. voltage across R_{rx}) is captured in Figure Q3E. Based on the voltage waveforms in Figure Q3E. Estimate the percent overshoot and undershoot of the digital pulse signal at RX, and explain, from the perspective of signal integrity why the time-domain signal at RX is badly distorted. *Hint: Use the data in Figure Q3D.*

(iv) Suggest an approach to reduce the time-domain signal distortion at RX.

[3 + 2 + 10 + 2 marks]

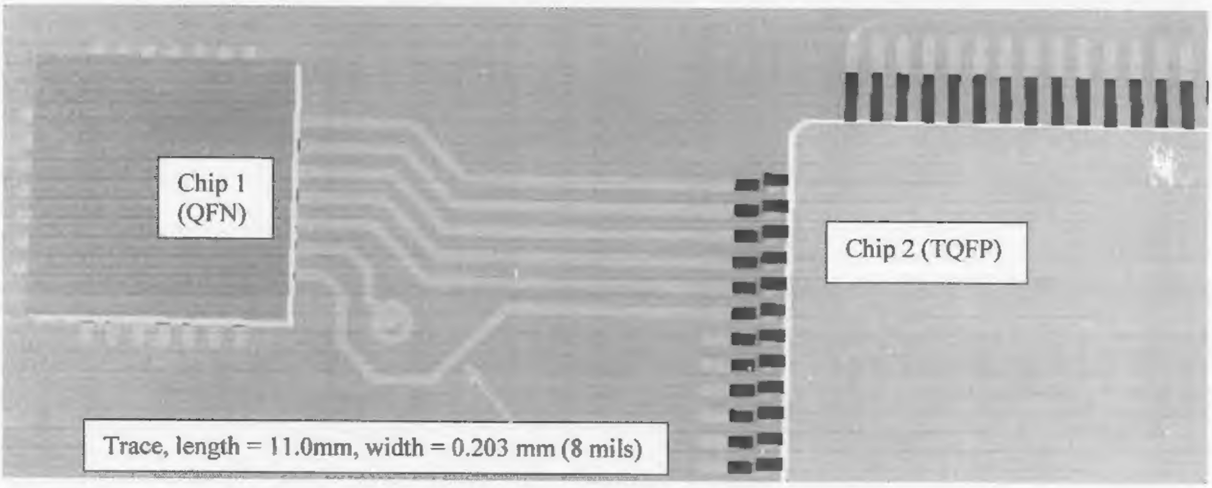

Figure Q3B – A small section of a PCB with two chips.

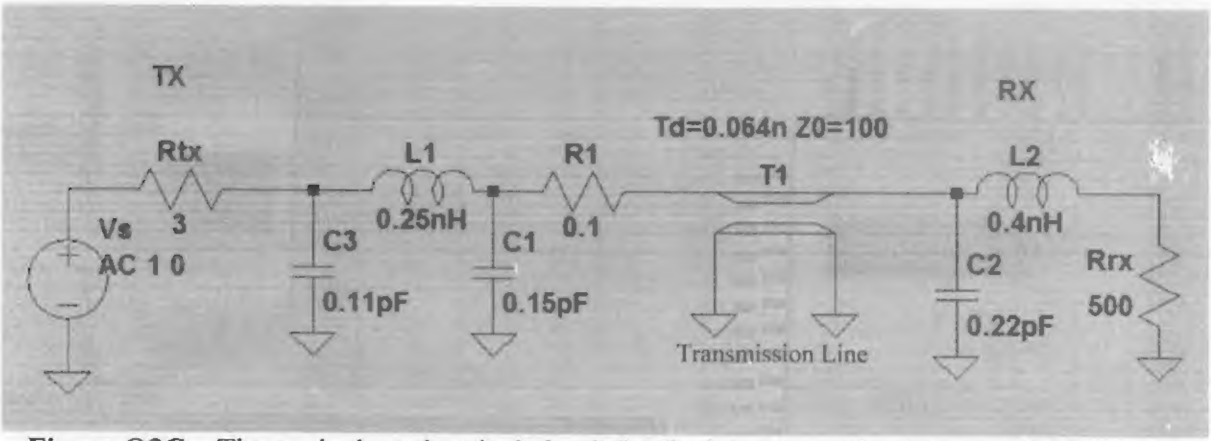

Figure Q3C – The equivalent electrical circuit for the interconnection between TX in Chip 1 and RX in Chip 2.

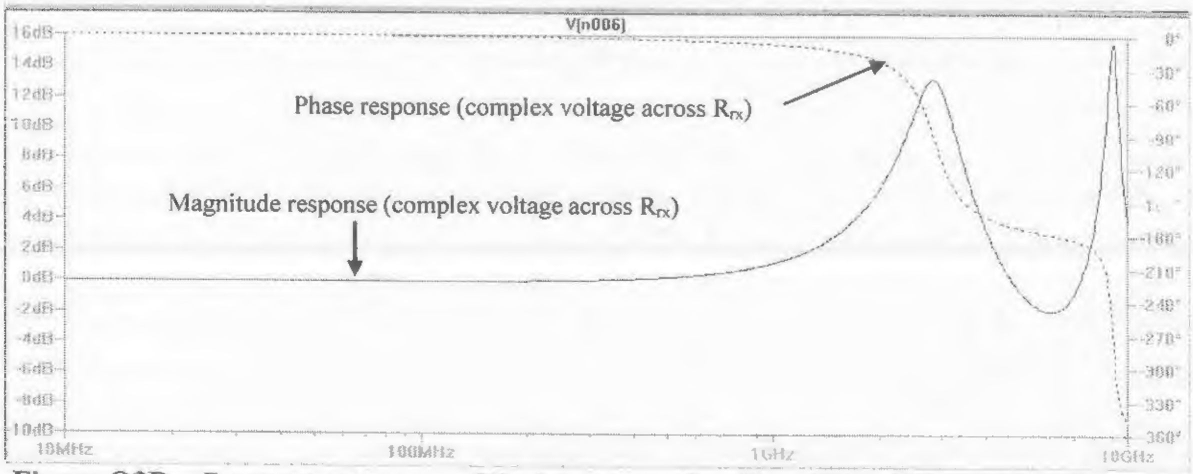

Figure Q3D – Frequency response of the interconnection (from TX to RX), measured at R_{rx}.

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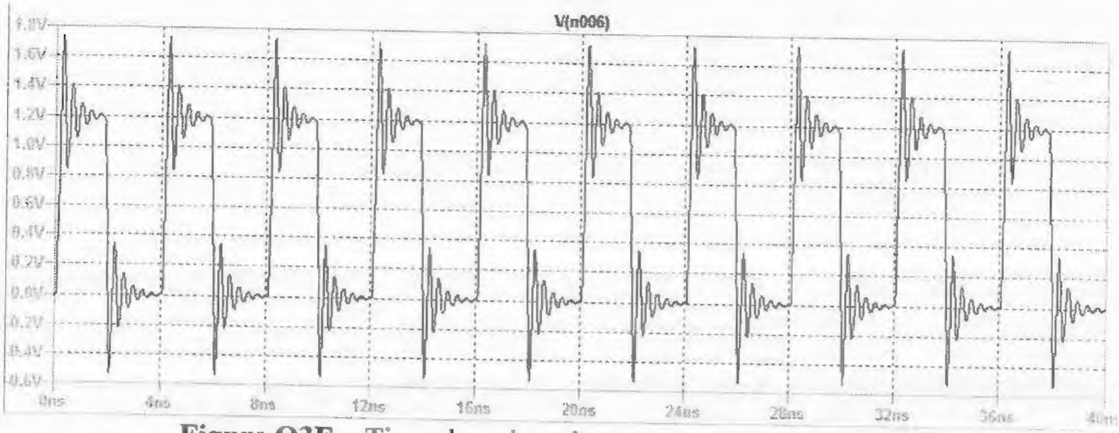


Figure Q3E – Time-domain voltage across R_{rx} inside Chip 2.

Question 4

(a) Briefly explain the difference between *wear out* and *over-stress* failure mechanisms in relation to electronic packaging. Give TWO (2) examples for each mechanism.

[2 + 4 marks]

(b) List THREE (3) types of accelerated testing on components or products and highlight the feature of each test.

[6 marks]

(c) The failure rate versus time-in-use for a 8 GByte memory module is shown in Figure Q4 (Statistics can be estimated based on accelerated environmental testing and transform). Suggest a warranty period for the module and briefly explain your choice.

[3 marks]

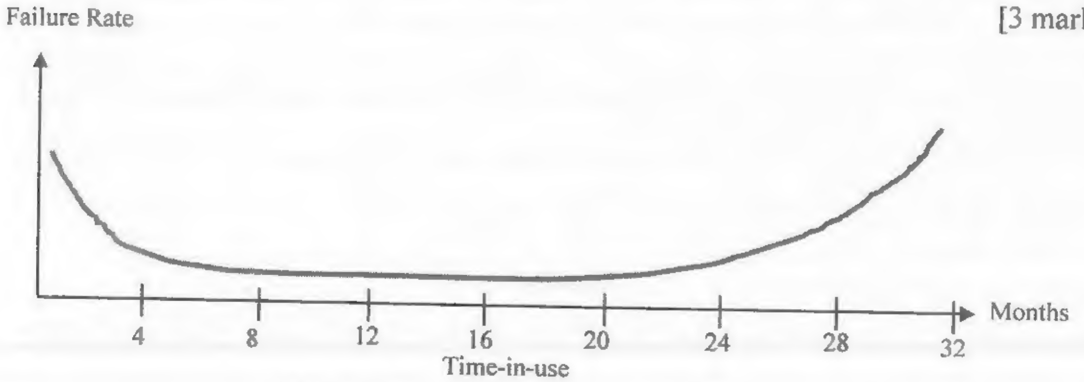


Figure Q4 – Failure rate versus time-in-use.

(d) A new molding compound is used in the packaging of a 32-bits microcontroller chip. An initial batch of 900 chips is put through a temperature shock accelerated cycle test. After every 20 cycles, a functional test is performed to weed out the failed units. Table Q4 shows the data after 260 cycles. Each cycle lasted 1 hour.

(i) Find the average failure rate after 260 cycles.

Continued...

(ii) Estimate the values of the four reliability functions, i.e. the cumulative failure function *F(n)*, the reliability function *R(n)*, failure density function *f(n)* and failure rate *h(n)*, at $n = 100$ cycles.

[3 + 7 marks]

Number of temp. shock cycles	Number of fail units
20	62
40	48
60	56
80	50
100	46
120	79
140	60
160	58
180	62
200	34
220	28
240	43
260	69

Table Q4 – Fail units versus shock cycles.

Appendix – Useful Formulae

Mechanical Relations (Only formulae for x direction and y-z plane are shown, formulae for y and z directions, x-y and x-z planes follow similar form)

L_x = length in x direction in m.
Δx = change in length in x direction in m.
Δy = change in length in y direction in m
A = y-z plane cross section area in m^2
F_x = Force in x direction in N
F_y = Force in y direction in N

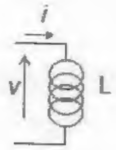
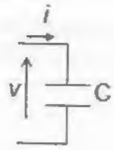
Tensile Strain on y-z plane in x direction $\varepsilon_x = \frac{\Delta x}{L_x}$	Shear Strain on y-z plane in y direction $\gamma_{yz} = \frac{\Delta y}{L_x}$
Tensile Stress on y-z plane in x direction $\sigma_x = \frac{F_x}{A}$	Shear Stress on y-z plane in y direction $\tau_{yz} = \frac{F_y}{A}$
Linear tensile Stress and Strain relation in x	Linear Shear Stress and Strain in y

direction $\varepsilon_x = \frac{1}{E_x}\sigma_x$ where E_x = Young's Modulus in x direction	direction $\gamma_{yz} = G_{yz}\tau_{yz}$ where G_{yz} = Shear Modulus in y-z plane
Poisson's Ratio $\nu_{zx} = -\frac{\varepsilon_z}{\varepsilon_x} \quad \nu_{yx} = -\frac{\varepsilon_y}{\varepsilon_x}$	Coefficient of Thermal Expansion $\alpha_L = \left(\frac{\Delta L}{L}\right)\frac{1}{\Delta T}$ Where L is the original length in m ΔL is the change in length in m ΔT is the change in temperature in °C or K

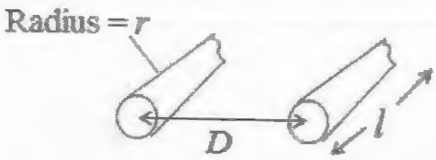
Thermal Relations

Heat Flow Equation in 1 dimension $q = -kA\frac{dT}{dx}$ with $\frac{dT}{dx} \cong \frac{\Delta T}{\Delta x} = \frac{T_2 - T_1}{\Delta x}$ Where q = energy transfer rate in W. k = Thermal conductivity in $Wm^{-1}K^{-1}$ or $Wm^{-1}{}^{o}C^{-1}$ A = Cross section area in m^2 Δx = Thickness of material in x direction.
Thermal Resistance $R_{th} = \frac{-\Delta T}{q} = \frac{\Delta x}{kA}$
Newton's Law of Cooling for convection $q = hA(T_s - T_f)$ Where h = Heat transfer coefficient for convection. A = Area of the wet surface. T_s and T_f are the surface and ambient fluid temperatures respectively.
Thermal Radiation Stefan-Boltzmann's Radiation Law $q \cong \varepsilon\sigma AT^4$ W Where ε = Emissivity of the surface (between 0 to 1, 1 for blackbody). σ = Stefan's constant, $5.6704\times10^{-8}\ Js^{-1}m^{-2}K^{-4}$. A = Surface area of the object. Peak wavelength for radiated power $\lambda_{\max} = \frac{2.8978\times10^{-3}}{T}$ m

I-V relationship for RLC elements

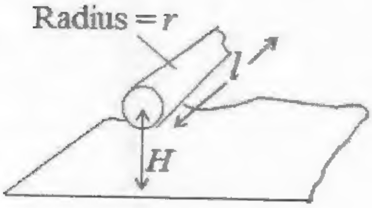
Time Domain		Time Harmonic or Phasor Form
$v(t) = Ri(t)$		$V(\omega) = RI(\omega)$
$v(t) = L\dfrac{di(t)}{dt}$		$V(\omega) = j\omega LI(\omega)$
$v(t) = \dfrac{1}{C}\int_{-\infty}^{t} i(\tau)d\tau$		$V(\omega) = \dfrac{1}{j\omega C}I(\omega)$

Approximate formulae for inductance and capacitance



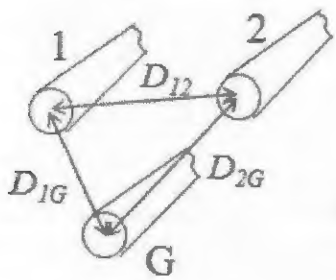
Assume $D >> r$

$$L \cong \frac{\mu l}{4\pi} + \frac{\mu l}{\pi}\ln\left(\frac{D-r}{r}\right)$$



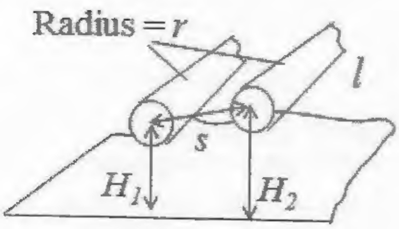
Assume $H >> r$

$$L \cong \frac{\mu l}{8\pi} + \frac{\mu l}{2\pi}\ln\left(\frac{2H-r}{r}\right)$$



$$M_{12} \cong \frac{\mu l}{2\pi}\ln\left(\frac{D_{1G}D_{2G}}{rD_{12}}\right)$$

All conductor radius = r



$$M_{12} \cong \frac{\mu l}{4\pi}\ln\left(1 + 4\frac{H_1H_2}{s^2}\right)$$

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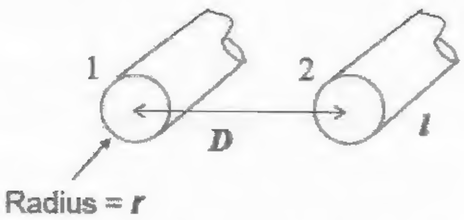
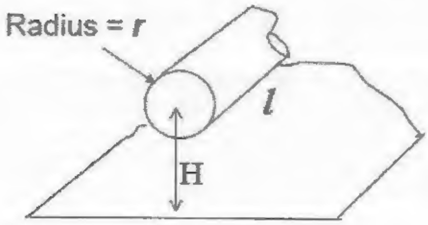


$$C = \frac{\pi \varepsilon l}{\cosh^{-1}\left(\frac{D}{2r}\right)}$$

If radius of conductor 1 & 2 are different:

$$C \cong \frac{2\pi \varepsilon l}{\cosh^{-1}\left(\frac{(D-r_1)(D-r_2)}{r_1 r_2}\right)}$$



$$C = \frac{2\pi \varepsilon l}{\cosh^{-1}\left(\frac{H}{r}\right)}$$

Bandwidth of random digital pulse (approximated to trapezoidal shape)

$$BW_{pulse} \cong f_{knee} = \frac{1}{\pi \tau}$$

Important formula for Reliability Mathematics

$$\text{Average Failure Rate} = \frac{\text{Total number of failures}}{\text{Total number of device - hours}}$$

$$\text{MTBF} = \frac{1}{\text{Average Failure Rate}}$$

$$\text{FIT} = \text{Number of failures per billion device - hours}$$

$$R(t) = \frac{\text{Number operating at } t}{\text{Total number of devices}}$$

$$F(t) = \frac{\text{Total number failed at } t}{\text{Total number of devices}}$$

$$f(t) = \frac{dF(t)}{dt}$$

$$h(t) = \frac{f(t)}{R(t)}$$

$$\text{MTTF} = \int_0^{\infty} t f(t)\,dt$$

End of Paper.